(12) UK Patent Application (19) GB (11) 2 347 503 (13) A

(43) Date of A Publication 06.09.2000

(21) Application No 9904971.0

(22) Date of Filing 05.03.1999

(71) Applicant(s)
Peter Oliver
Lower House, The Chequer, Bronington, SY13 2JQ, United Kingdom

Kevin Doughty
Bryn Dedwydd, North Road, CAERNARFON, Gwynedd, LL55 1BE, United Kingdom

(72) Inventor(s)
Peter Oliver
Kevin Doughty

(74) Agent and/or Address for Service
Peter Oliver
Lower House, The Chequer, Bronington, SY13 2JQ, United Kingdom

(51) INT CL^7
A61B 5/00 , G06F 17/00

(52) UK CL (Edition R)
G1N NESS N30B N30P2 N30P5 N30P8 N30P9 N30R

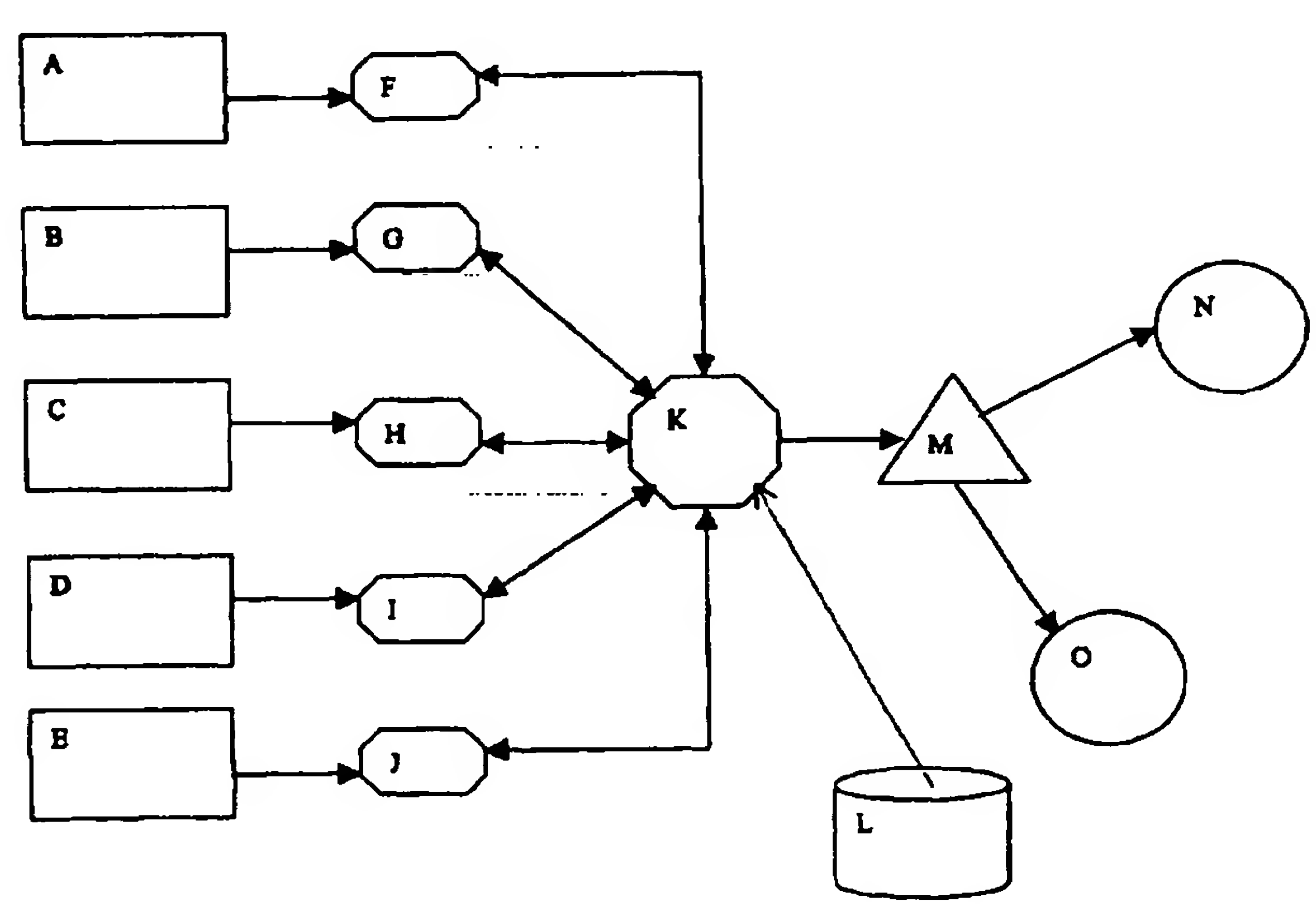
(56) Documents Cited
GB 2285135 A GB 2243691 A US 5544661 A

(58) Field of Search
UK CL (Edition Q) **G1N NEAN NENX NESS**
INT CL^6 **A61B 5/00**
Online: WPI, EPODOC, JAPIO

(54) Abstract Title
Intelligent remote sensor for veterinary applications

(57) This invention satisfies a need for an array of simple non-invasive sensors, which can be integrated in a modular manner into a harness, or similar arrangement, which allows them to be worn by the animal in a continuous or nearly continuous manner. The data generated by the sensors can then be transmitted off the animal for analysis or recording or might be analysed locally using an intelligent system which acts as a pre-preprocessor to identify indicators of difficulty or need. The outputs of the pre-processors may be combined in a form which produces a dynamic health or need index. If the value of this index changes to lie outside the bounds programmed for that animal then an alert may be transmitted using telemedicine principles. This dispersed intelligence arrangement may be ideally suited to applications in animal breeding stations and zoos as well as for the general monitoring of valuable animals that are kept outside the home.

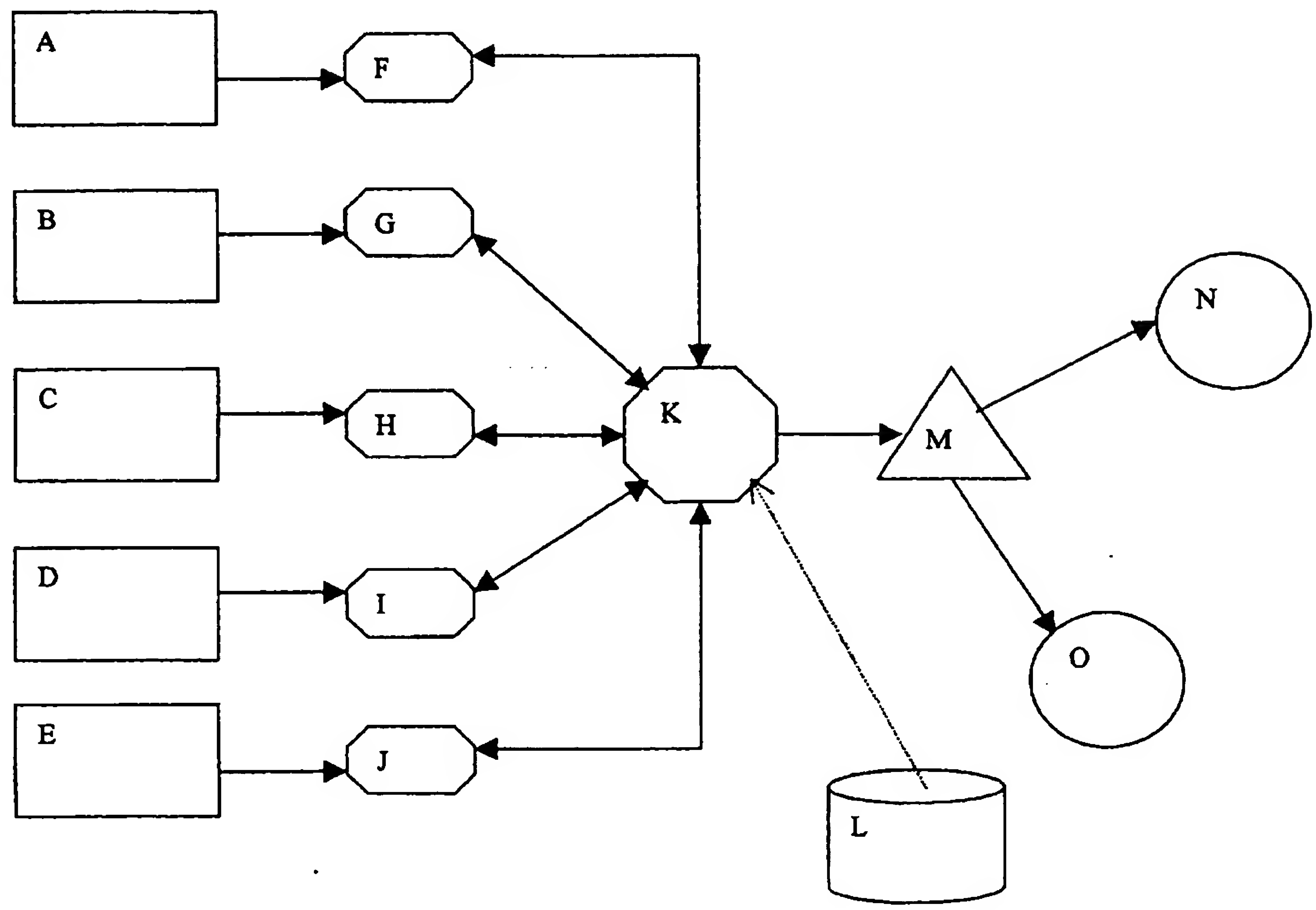
Figure 1:



GB 2 347 503 A

BEST AVAILABLE COPY

Figure 1: A schematic diagram of the animal telemedicine scheme



2347503

"A MULTI-SENSOR INTEGRATED, MODULAR AND INTELLIGENT METHOD OF DETECTING HEALTH EMERGENCIES IN ANIMALS REMOTELY"

Background to the Invention

Animals such as dogs, cats and horses have always been important to families in the UK. They are a source of love, friendship and companionship. Consequently, millions of pounds are spent on their health and welfare every year. Although food bills take up most of these costs, substantial amounts are also spent on veterinary fees as owners try to provide the equivalent of human health provision. These fees can be very great especially when larger animals are involved.

Unfortunately, animals are unable to indicate general feelings of ill health to their owners or to their vets. Hence, it is necessary to combine general observations of activity and habit with rather more limited physiological data in order to determine the health status of an animal. This can lead to long delays in the commencement of treatment and, indeed, can cause much suffering to the animal in question.

Many larger animals have a very high associated value, which justifies a greater investment in the general monitoring of health status. Consequently, junior members of staff are often called upon to live with an animal during times of illness so that changes in condition may be detected at an early stage and appropriate interventions made if appropriate. Closed circuit television cameras may be used additionally though the output must be monitored continuously if an early warning is to be effected.

An example of a situation where continuous monitoring may be required is in the detection of labour. Many animals, including horses and other large mammals, may need help in giving birth. Indeed, failure to provide assistance at the appropriate time may result in the death of the offspring. This may be emotionally upsetting to the animal and to the owner but in the case of thoroughbred horses, for example, may also be financially disastrous as each foal might have a value of several thousand pounds.

There have been previous attempts at providing an early warning of imminent foal delivery using both sweating sensors and temperature sensors. Both have proved unreliable and have given rise to false alarm conditions. Indeed, other attempts at detecting the late stages of labour have involved a measurement of tail activity though this has been unpopular with breeders because of the difficulty of attachment.

The idea of integrating a sensor or sensor array into a wearable device (i.e. an item of clothing or a harness) is not new and may be relevant to humans. However, an application of such technologies for use with animals must also solve the problems of fitting and of providing automatic alerts due to the animal's inability to respond in the required way.

It may be evident that there is a need for a wholly reliable method of determining health status unambiguously. This will depend not only on an array of physiological sensors but also on artificial intelligence to provide a degree of data pre-processing so that only relevant unusual characteristics are detected. It would appear that no single measurement could provide the level of certainty required so a combination of several sensing techniques must be relevant to provide the required level of reliability. Furthermore, some sensors may be more effective than others in providing appropriate warnings of need. Thus, the outputs of the pre-processors need to be combined in some unique manner in order to demonstrate relevance to all situations and for all animals.

Although a vet might ideally wish to examine the physiological data on a continuous basis in order to make an assessment, in practice, the time scales involved may be so long that further artificial intelligence may be required to detect the emergency situations without any previous involvement of the vet. The intelligence in such a monitoring system may be concentrated on the veterinary practice but this would involve the continuous transmission of data for an extended period of time. This implies that the optimum situation will involve a dispersed intelligence.

The present invention describes such a system, which may be used with any mammal and especially for the early warning of birth.

Description of the Invention

Measurement or observation of the following parameters may generally determine the health status of a large animal such as a horse:

1) basal temperature
2) pulse rate
3) breathing rate
4) breathing format
5) sweating characteristics
6) sound generation
7) stomach/uterus contractions
8) chest sounds
9) stomach sounds
10) muscular activity

Other more specialised measurements may be relevant to particular animal groups.

The parameters described above may be measured non-invasively, and hence without upsetting the animal, by integrating a number of sensors into a harness or blanket which may be fitted around the animal by a relatively unskilled person in a repeatable manner. For example, breathing characteristics including the breathing rate, the phase of breathing cycle compared with the movement of the diaphragm, cough sounds and wheezes and the inhale to exhale ratio may be monitored using a combination of strain gauges mounted on an appropriate substrate. Contractions or muscle spasms in the stomach (or uterus of a female) may be measured in the same way. Temperature may be measured by one of a number of methods including the inclusion of a dedicated microchip or by making use of the temperature dependence of a PCB track's resistance or that of capacitative or inductive elements included on a flexible PCB used as the substrate for the electronic circuits.

Sounds from the lungs, the heart or the stomach may be detected using a miniature piezoelectric microphone or by developing a distributed low frequency sound monitor using piezoelectric wire for example. Appropriate low-pass filtering would yield the heartbeat from which the pulse rate could be derived while high pass or adaptive filtering would allow spectral and intensity analysis to be performed to identify the nature or coughing or rumbling behaviour. Alternatively, the heartbeat may be measured directly using ECG electrodes and an appropriate coupling gel or by using impedance plethysmography on a limb.

Sweating rate may be measured as a change in surface conductivity. This may be detected by simply measuring the current flowing between two sets of adjacent electrodes on the surface of the animal or its skin. However, a more sensitive arrangement might involve use of a four-point probe technique in which the potential drop across two inner electrodes is measured when a signal is applied to an outer pair of electrodes. This signal can be in an alternating current form in order to avoid effects such as electrode polarisation and to enable lower potentials to be used in conjunction with narrow band filters or phased lock loop circuits thus reducing the possibilities of providing the animal with an electric shock.

General sounds, such as snorting, from the animal's mouth may be detected using further microphones or distributed transducers placed to the front of the harness. When used with a high pass filter (rejecting sounds below 100Hz.) this may be used to monitor generated sounds.

Finally, general activity may be measured directly on the animal using various tilt or inclinometer devices, or by using dedicated techniques involving piezoelectric wire wrapped around the upper limbs, or by measurement of an electromyograph (EMG), or by analysis of motion artifacts induced in other physiological measurement circuits. Alternatively, if the animal is confined to a stable or some other yard or building, its motion may be monitored using a passive infra-red movement detector.

It may apparent that not all these sensors may be needed at all times and for all animals. However, a minimum of 5 may be required to provide statistical certainty regarding the nature and origin of any emergency.

For each sensor, i, it is possible to define normal, unusual and emergency states, a, for any animal and for any particular physiological situation. Indeed, an experienced vet might further sub-divide these states so that a score a_i might be applied i.e. normal might mean $a_i = 0$, slight irregularity might mean $a_i = \frac{1}{4} = 0.25$, unusual implies $a_i = 2/4 = 0.5$, very unusual implies $a_i = \frac{3}{4} = 0.75$ and emergency means $a_i = 4/4 = 1$.

The relevance of each measurement would be a function of the animal type and of any other concerns or dangers. These might be described by a weighting function, b_i which might range from 0 to 1 Thus, the contribution to a Danger Index (DI) for this sensor would be $a_i \times b_i$. For 5 sensors, we might add the respective contributions such that:

$$DI = a_1 b_1 + a_2 b_2 + a_3 b_3 + a_4 b_4 + a_5 b_5 \quad \text{.........................} \quad \text{eq. (1)}$$

where the subscript 1 refers to sensor 1 and so on

This would imply that the danger index increases as the number of sensors increases. This cannot be the case so a normalisation is required such that the range of DI ranges from 0 for a completely

normal situation through to 1 for a certain emergency. This may be achieved by dividing by i, the number of sensors.

i.e. $DI = (a_1 b_1 + a_2 b_2 + a_3 b_3 + a_4 b_4 + a_5 b_5) / i$ .... eq. (2)

e.g. for a system with 5 sensors,

$$DI = (a_1b_1 + a_2b_2 + a_3b_3 + a_4b_4 + a_5b_5) / 5$$

It may be apparent that this function can only reach its maximum value of 1 if all sensors are relevant and weighted equally at 1. This may not generally be the case. In practice, the sensors selected would rarely provide the perfect analysis. Consequently, a decision to intervene would almost invariable be based upon incomplete information i.e. a danger index (DI) somewhat less than 1. This is no different to real-life consultations both for animals by vets and, to a lesser extent, for humans visiting a doctor. It is only the skill and experience of the profession which enables him or her to arrive at a judgement and to determine the need for intervention and/or treatment. In effect, the physician is determining the health risk based on a mental calculation of some risk index in the knowledge that he may call for further tests if the result is marginal.

In remote applications of medicinal knowledge (i.e. in telemedicine applications), there is usually no opportunity to add extra data which means that the physician must establish a set of rules. In animal telemedicine, the lack of patient participation in the process demands that clear quantitative assessments techniques are applied and that the artificial intelligence in the system is enabled to perform the calculations and, effectively, to make the clinical decisions.

In the present invention, the sensors, decision processors and communications within the system are described in Figure 1 for a simple application involving only 5 sensors. The 5 sensors are labelled A to E inclusive. Each provides appropriate physiological data to a dedicated pre-processing unit labelled F to J inclusive in Figure 1. These pre-processing units may be attached directly to the sensors (and hence on the animal) or they may be off the animal and connected using appropriate wireless technology. The preprocessing units perform suitable counting, timing and other calculations on the data in order to derive some quantitative measure of a health parameter. For example, one might take data from a respiration sensor in order to derive the breathing rate. This may be compared with a set of bounds which have been previously programmed into the system through the main processing unit labelled K using a suitable programming interface labelled L in Figure 1. In its simplest form, the information on set bounds would be held in the main processing unit, K. However, in the more general case involving dispersed intelligence, each pre-processor, F to J, may compare the measured quantities with the set bounds in order to pass on a processed factor of the form a_i.

The main processing unit, K, (which can either be on the harness attached to the animal or close by in the animal's sleeping quarters) collects the factors a_i and calculates a danger index (DI) using values of the parameters b_i that have also been programmed in for the particular animal (and for each potential health problem) by the veterinary surgeon using an equation of the form shown in equation (2).

The main processing unit will also have been programmed with intervention thresholds and instructions on how to response to a danger index above a defined limit. It is connected to a communications interface labelled M in Figure 1. This consists of a message generation system together with a transmission unit. The message generator will convert a code produced by the main processor unit K into a speech message for analogue transmission or into another coded message for digital transmission. Generally, the signal will be transmitted using a wireless link between the system that is local to the animal and a receiver which may be in one of several locations. Indeed, the messages may be directed to different receivers according to the required response. For example, if the system is reporting a routine analysis which shows that the health is good (i.e. danger index is low) then this may be sent to the owner or his computer (labelled N in Figure 1) to provide a "comfort" message. However, if the danger index rises and intervention is required, then the alert must go to the veterinary surgeon (labelled 0) using perhaps a telephone modem link with sufficient intelligence to recognise the identity of the animal, the location of the animal, and the level of the alert.

In its simplest form, all the sensors would have equal status

i.e. $b_1 = b_2 = b_3 = b_4 = b_5 = 1$.

The sensors would also be capable of only differentiating between normal and abnormal situations

i.e. $a_i = 0$ or $a_i = 1$ for $i = 1$ to 5.

Inserting these data into equation (2) we find that

DI = 0, 0.2, 0.4, 0.6, 0.8 or 1 depending on how many of the sensors report an abnormal situation. If the vet had set a threshold of 0.5 for DI then an alert would be produced if 3 or more sensors reported an alert. This approach clearly overcomes any problems with any individual sensor and prevents false-alarms whilst enabling a vet to priority his response.

Practical Application

The sensors from 1 to i will be integrated into a harness or blanket which covers the animal whilst providing a means of protection from environmental conditions, interconnectivity and location for electronic components through flexible PCBs, immunity from r.f. interference, and a housing for power supplies (batteries), transmitter modules, aerials and some elements of dispersed intelligence. This harness may be fitted initially by the vet but may be generally so simple to put onto an animal in a repeatable manner that the owner/trainer may put on the device whenever appropriate. The vet will connect a lap-top computer to a socket on the harness in order to program the required firmware for the current application. This will involve the activation of certain (but not necessarily all of) the sensors and a setting of status threshold for each sensor for that particular animal and the problems that are likely to be detected. For example, a breathing rate of less than 25 breaths per minute may be considered normal (a = 0), a rate of 25 to 35 may be considered slightly abnormal (a = 0.25), a rate of 35 to 50 may be considered to be unusual (a = 0.75) and a rate above 50 breaths per minute considered to be indicative of an emergency (a = 1).

It would also involve the thresholds for intervention. For example, a danger index (DI) of 0.4 may be used to generate a first alert signal while a value of 0.6 may be used as a definite indicator of an emergency which required immediate assistance.

This approach may be particularly useful in providing an early warning of an imminent birth e.g. for a horse in labour. It is well established that many mares become restless during foaling. This may be observed as a tendency to get up and sit down with increasing frequency, a tendency to roll over, to sweat and to suffer increased heart-rate and breathing. The final physiological symptom will be the actual contractions of the uterus associated with labour. In such a case, the present invention would rely on a combination of these sensors to determine the onset of labour, thus effectively eliminating the possibility of a false alarm.

The system might also record the relevant values of the measured parameters as a function of time prior to the actual emergency alert. Thus, the vets could retrospectively analyse the data in order to improve their own ability to set the appropriate thresholds for the system response.

By adding appropriate software, the system may become a long-term monitoring tool for continuous use in places such as zoos where dangerous animals cannot easily be accessed for routine health checks by vets.

Claims

1) A remote, modular distributed intelligence system for the detection of health emergencies in animals consisting of:

    a number of electronic sensors fabricated into a harness which attaches to the animal,
    pre-processing electronic modules which analyse the outputs of the sensors,
    a main processing unit which processes the outputs of the pre-processing modules,
    an intelligence unit which makes decisions based on parameters that have been programmed into the unit by the vet,
    a means of coding the decisions in the form of a code for transmission,
    a transmission interface/unit which relays data from the vicinity of the animal to a vet or other interested party,
    a receiver unit which decodes and interprets transmitted messages, and
    a means of relaying messages to the appropriate parties.

2) A system as described in 1) in which the sensors are non-invasive electronic sensors to measure physiological parameters and activities.
3) A system as described in 1) in which the intelligence is dispersed throughout the system.
4) A system as described in 1) which is modular in nature.
5) A system as described in 1) in which the sensors and their electronic circuitry are fabricated on a flexible PCB.
6) A system as described in 1) in which the outputs of certain sensors may be selected for particular animals or health conditions.
7) A system as described in 1) which may be used to perform a continuous monitoring of an animal's health status.
8) A system as described in 1) which may be configured to provide telemetry for the visualisation of physiological parameters by a veterinary surgeon.
9) A system as described in 1) which can provide a variety of different alert messages according to the analysis of the data from the sensors.
10) A system as described in 1) which can provide a remote assessment of the health status of a dangerous animal such as a lion or a tiger.
11) A system as described in 1) which can provide a remote assessment of a very large animal such as a horse, a hippopotamus or an elephant.

12) A system as described in 1) which can provide a remote assessment of small animals such as dogs and cats.

13) A system as described in 1) which can be used to detect the earliest stages of labour.

14) A system as described in 1) which can avoid false alarms through the use of a number of independent sensors.

15) A system as described in 1) which may be used to detect the onset of a particular illness.

16) A system as described in 1) which may be used to monitor the progression of a particular illness.

17) A system as described in 1) which may be used to remotely study the effectiveness of a therapy in treating a condition.

18) A system as described in 1) which may be used to remotely study the effects of new drugs in treating an illness.

19) A system as described in 1) which may be used to remotely assess the health of animals living in the wild.

20) A system as described in 1) which may be used by vets to monitor the progress of animals following surgery.

21) A system as described in 1) which may be used to assess trauma.

22) A system as described in 1) which may be used to determine the optimum combination of sensors for remote assessment of condition.

23) A system as described in 1) which may be used to monitor the mating habits of animals.

24) A system as described in 1) which may be used to monitor the health of humans on a continuous basis.

25) A system as described in 1) which allows emergency messages to be sent to different responders.

26) A system as described in 1) which may be used with a telephone-based response scheme.

27) A system as described in 1) which may be used in conjunction with cellular phones.

28) A system as described in 1) which may be used to activate a closed circuit television system.

29) A system as described in 1) which may transmit image data using wireless telemetry the public switched telephone network.

30) A system as described in 1) which may provide dynamic assessment of health status.

The Patent Office

INVESTOR IN PEOPLE

Application No: GB 9904971.0
Claims searched: 1-30

Examiner: E QUIRK
Date of search: 28 June 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): G1N(NEAN, NENX, NESS)

Int Cl (Ed.6): A61B(5/00, 5/07) G06F(17/00)

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2 285 135 A	(Hewlett-Packard) Whole Document	1,2,4
X	GB 2 243 691 A	(Julian Murray Payne) See figure 4.	1-4,9,25
X	US 5 544 661	(Charles L Davis) Whole Document	1-4,6-9, 26,27,29

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.